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PAST UAV PROGRAM FAILURESAND IMPLICATIONS FOR CURRENT UAV PROGRAMS

by

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Abstract

There has been an increasing interest in the use of Unmanned Aerial Vehicles (UAVs) among the US armed services over the past 20 years. However, despite over four billion dollars in investment, the services have cancelled numerous development programs and achieved only marginal success with the fielded systems. This research will examine recent Department of Defense (DoD) UAV development efforts and identify common causes for the repeated failure of DoD UAV programs to become operationally robust. Two ongoing UAV development efforts, the RQ-4A Global Hawk UAV Advanced Concept Technology Demonstrator (ACTD) program and the X-45 Unmanned Combat Air Vehicle (UCAV) Advanced Technology Demonstrator (ATD) program, will then be examined for evidence that we are incorporating these lessons learned into our current programs.

Chapter 1

Introduction

Unmanned Aerial Vehicles hold great promise to perform many theater reconnaissance operations from surveillance targeting and bomb damage assessment. Beyond these, we are contemplating their use in a variety of other operations, from peacekeeping or peace enforcement to counterdrug, counterterrorism, peacetime surveillance and even strike operations.

—General Ronald R. Fogleman, former US Air Force Chief of Staff

Statement of the research question

Are there common causes for UAV program failures and are these causes being addressed in ongoing UAV development programs?

Background and significance of the problem

Unmanned Aerial Vehicles (UAVs) are presently being utilized by several countries for reconnaissance, surveillance, target location and battle damage assessment. In the future, UAVs are proposed as an alternative to manned aircraft for missions characterized by the three Ds: dull, dirty, and dangerous.[1] Dull means long-endurance missions which may become as long as several days due to the desired range and loiter time of the system. Dirty refers to operating in an environment that is contaminated by chemical, biological or nuclear agents. Dangerous missions include suppression of enemy air defense or other missions that require operation in high-risk areas. UAVs are uniquely suited to these tasks for a variety of reasons.

UAVs have several additional advantages over manned aircraft. The most obvious advantage of the UAV is the ability to penetrate enemy airspace without risking an aircrew. UAVs are generally less expensive than manned systems because they are designed to be expendable and therefore do not have the system redundancy of manned aircraft. The elimination of the aircrew and related life support systems may allow UAVs to be smaller than manned aircraft. Smaller size can increase survivability through reduced radar cross section, and smaller engines producing a lower infrared signature and reduced noise levels. Smaller size improves transportability, making them rapidly available to serve in any crisis around the world.[2] These advantages make UAVs an attractive solution for many missions currently performed by manned aircraft.

Defense industry analysts predict that UAVs will eventually conduct almost all missions now assigned to manned aircraft, from intelligence gathering and counterair operations, to operational and even strategic attack.[3] UAV payloads have been developed to detect the presence of chemical or radiological agents in the air. These systems have been used to perform electronic warfare before an attack in an effort to degrade enemy air defenses. UAVs can serve as a communication relay platform for enhanced coordination of ground forces or as an aid to search and rescue operations. Payloads are under development to allow UAVs to identify and track communications signals in order to augment KC-135 Rivet Joint aircraft.[4] Additional demonstrations have been proposed to use these air vehicles to complement the E-3 AWACS and E-8 JointSTARS fleet. These high-value assets could be utilized more effectively if companion UAVs were available to fly closer to the forward edge of the battle area and overcome limitations due to range and geography.[5] The potential utility of these systems has lured the Department of Defense (DoD) to invest heavily in UAV development.

According to the Congressional Budget office, the Department of Defense spends about $600 million a year on UAV programs, but has historically had trouble developing and fielding UAV systems.[6] During a time of stagnant defense budgets, the global UAV market is expected to grow from $2.4B today to $4.6B by 2005.[7] This paper will attempt to examine some of the reasons that UAVs have failed to deliver on the promise of an affordable, reliable alternative to manned aircraft and will show how our current programs are attempting to avoid these pitfalls.

Limitations of the study

Since the end of the Vietnam war, DoD has begun at least nine UAV programs that were later cancelled.[8] There is not sufficient room in this paper to examine all nine programs as well as the programs that were fielded. Chapter 2 "Recent Programs" reviews the five programs that, in the opinion of the author, involved the greatest investment of time and effort on the part of the services. Each service currently has at least one UAV system in development. Chapter 4 "Current Systems" addresses the High Altitude Endurance (HAE) UAV and Unmanned Combat Air Vehicle (UCAV) programs, since these programs have the greatest visibility within the U.S. Air Force.

Overview of the document

An introduction to UAV issues and missions is provided in Chapter 1. Chapter 2 examines recent Department of Defense UAV development efforts and identifies common causes for the repeated failure of DoD UAV programs to become operationally robust. Chapter 3 reviews the ongoing RQ-4A Global Hawk UAV ACTD program and the X-45 UCAV ATD in light of these common causes. Conclusions are summarized in Chapter 4.

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Chapter 2

Review of Recent UAV Programs

> *The key premise is this: UAVs saved lives. They not only supply intelligence, but take the pilot out of high risk situations. When F-16 pilot Scott O'Grady was shot down, it was a crisis, but when a $2 million Predator UAV was shot down, it was a curiosity. Who is going to tell a parent that their child is not worth $2 million?.*
>
> —Major General Kenneth R. Israel, former Director, Defense Airborne Reconnaissance Office

The Department of Defense increased its interest in UAVs following our experiences in Lebanon in the mid-1980s. In 1984, the U.S. Navy conducted an air strike in Lebanon, during which the Palestinian Liberation Organization shot down two aircraft and captured one of the crew.[1] The Secretary of the Navy requested a study to identify methods of lowering the risk to U.S. combat personnel. The study revealed the U.S. was risking tactical manned platforms to obtain target information in Lebanon while the Israelis were using UAVs to perform the same mission.[2] Although the Army had initiated the Acquila UAV program to develop an unmanned artillery spotting capability, the Navy had been reluctant to pursue UAV systems. Secretary Lehman, acting on the results of this study, directed the Naval Systems Command to purchase several Mastiff UAVs from Israeli Aircraft Industry's Malat Division.[3] These UAVs were employed as an interim capability and evaluated for military utility, which further increased the visibility of UAV systems within the services.

Pioneer UAV Program

Figure 1: Pioneer UAV Shipboard Launch

The Pioneer UAV system was a follow-on to the Navy's purchase of Mastiff UAVs in 1985. The Navy's experience with the Mastiff UAV identified several shortcomings. While capable of shipboard launch and recovery, the Mastiff UAV only carried a daylight video sensor, and had limited range and endurance.[4] The Pioneer UAV was also purchased as a non-developmental system directly from the Israelis. The Pioneer has an endurance of five hours with a combat radius of 200 kilometers, and is equipped with either an infrared or daylight video sensor.[5] The Navy purchased nine systems, each with eight air vehicles for $87.7M and put the system into immediate operation.[6]

Navy and Marine Corps users identified a number of deficiencies with the Pioneer system. General Charles C. Krulak, Commandant of the U.S. Marine Corps, said, "Unfortunately, the Pioneer has too many limitations. First, the Pioneer does not have an automatic take-off, landing, or mission execution capability that has led to a high accident rate. Second, since the UAV telemetry is calculated at a Ground Control Station (GCS) that is incapable of integrated data dissemination, we lose the ability to pass this information quickly to the units that need it. Third, because it lacks weatherproofed avionics and has no Synthetic Aperture Radar (SAR) capability, the Pioneer is useless in bad weather".[7] Additionally, Marine Corps users felt the system needed a more reliable engine, better endurance, and a reduced logistical footprint.[8] Due to the accelerated nature of the procurement, these shortcomings were discovered during operations rather than during testing, which increased the cost of modifications.

The decision to purchase an existing UAV system and adapt it for shipboard use was a disappointment for the U.S. Navy. The requirement for shipboard operations was not adequately examined as part of the procurement decision. The UAV was deemed capable of ship-based operations, although the Pioneer UAV had never been employed from a ship by the Israelis and supporting data did not exist.[9] During the initial system deployment, electromagnetic interference aboard ship attributed to several UAV crashes. The "failure of overstressed small engines" and the failure of communication links also attributed to a high crash rate.[10] The Navy was forced to reprogram funds for an upgrade program to correct electromagnetic interference (EMI) and other deficiencies and make Pioneer "minimally capable".[11] The Navy eventually spent over $50M redesigning the systems, which was more than 50% of the original procurement cost.[12] The process of buying an off-the-shelf system without adequately testing operational suitability led to the fielding of a marginal system at a much higher cost than expected.

Although the Pioneer UAV system never met its original performance requirements, it remains in service with the US Navy and Marine Corps simply because there is no alternative. The high operations and support costs have led to the reduction from ten deployable squadrons to four.[13] An effort to replace the Pioneer UAV with the Outrider UAV has failed, as will be discussed later in this chapter. The Pioneer UAV is expected to remain in the Navy and Marine

Corps inventory until 2004 when its replacement system, the helicopter-like "Firescout" becomes operational.[14]

Acquila UAV Program

The Army initiated the Acquila UAV program in 1979. The Acquila UAV was developed to provide an unmanned over-the-horizon laser target designator capability for the Copperhead artillery projectile.[15] The program was originally estimated to cost $123M for development, followed by $440M to procure 780 air vehicles and associated ground control system equipment.[16] The development phase was expected to last four years, but was extended due to the slow development of critical technology and changing requirements.

New requirements intended to increase the systems survivability against Soviet air defenses increased the complexity of the system and made Acquila rely on immature technologies. An electro-optical/infrared (EO/IR) sensor integrated with a laser designator did not exist at the time and had to be developed along with the air vehicle.[17] The Army introduced the requirement to conduct autonomous operations to ensure the continuation of a mission if the data link was lost or jammed. This capability drove the need for a lightweight, jam-resistant data link, which did not exist at the time with adequate video image quality. The complexity of the Acquila flight control system was increased to allow the vehicle to follow a preprogrammed route beginning with an automatic launch sequence.[18] The mismatch between requirements and the available technology led to further delays and cost growth.

The development phase of Acquila was extended from 43 months to 79 months during which the Army invested over $1 billion.[19] At the end of the development phase, production was expected to exceed another $1 Billion even with a reduction from 780 to 376 air vehicles.[20] The final blow came when operational testing concluded that the system could not meet requirements on 98 of 105 flights.[21] The program was cancelled in 1987 and the Army turned its attention to the development of the Hunter UAV.

Hunter UAV Program

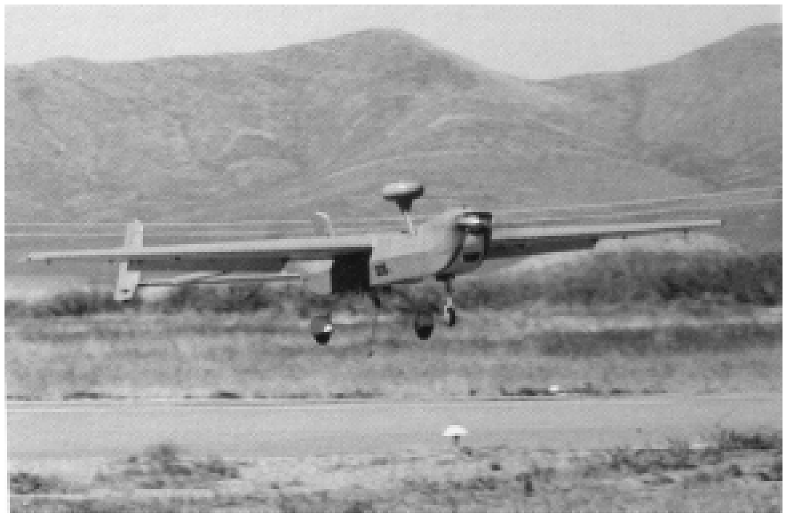

Figure 2: Hunter UAV

After the expensive fiasco of Acquila, the Army turned back to the simpler remotely piloted vehicle concept in 1988. The Hunter system was designed to support Armored Calvary Regiment commanders at ranges of up to 300 km with 8 hours of endurance on station. The program was originally estimated to cost $1.2B for the development and production of 50 systems with 400 air vehicles and associated equipment.[22] Development problems quickly formed and the cost and schedule estimates grew substantially.

Management and contracting limitations contributed to developmental problems of the Hunter system. The Hunter UAV had been developed by Israeli Aircraft Industries, but conditions of the U.S. Army contract forced them to team with an American partner, TRW. Further restrictions were placed on AIAs role in the program and much of the engineering knowledge of the system had to be reconstructed by TRW including the maintenance of software code that had been written in Hebrew. This management structure effectively isolated the American and Israeli teams and left the TRW ill-prepared to respond to problems identified during testing.

Significant problems with system performance and suitability were revealed during Limited User Testing (LUT) in 1992. The LUT testing found that the system was unable to relay video imagery and did not meet Army time standards for artillery adjustment.[23] The Government Accounting Office declared the system unsupportable, requiring excessive contractor maintenance to keep it operating.[24] The reliability of the air vehicle engines was so low that each UAV unit equipped with 2 Hunter systems could be expected to replace between 3 and 10 engines per week.[25] Rather than delaying Low-Rate Initial Production (LRIP) in order to complete development, the Defense Acquisition Board (DAB) approved the purchase of seven Hunter systems in 1993, at a cost of $171 million.[26]

In addition to the cost of producing the initial systems, the Army spent over $700M to continue development over the next three years. In 1995, acceptance testing of the initial Hunter systems identified further problems that led to the cancellation of the Hunter program. Additional problems were found with the flight control software, engine reliability, and the data link.[27] In 1996, the Chairman of the Joint Chiefs of Staff recommended the program be terminated. At the time the program was cancelled, the estimated development and production cost had grown from $1.2 Billion to $2.1 Billion.[28] Following the termination of the Hunter LRIP contract in 1995, the Army mothballed the majority of its Hunter systems and initiated the Outrider UAV program.

Outrider UAV Program

Figure 3: Outrider UAV

The Outrider UAV program was the first Army UAV program to be declared an ACTD. In 1994, the ACTD concept was introduced to improve and accelerate the DOD acquisition process. Traditional acquisition procedures are based on the assumption that relatively large numbers of systems are going to be procured and that they are to be employed in a well-understood concept of operations.[29] The size of the investment and stability of the Concept of Operations (conops) justifies the time and cost of the oversight process. The ACTD process was developed to address systems that did not fit these criteria, particularly systems where employment tactics needed to be developed along with the hardware.[30] This was certainly the case for the Outrider UAV, which appeared to be a good candidate for an ACTD.

The Outrider system was initially designed as a land-based tactical UAV system to support Army maneuver brigade and ACR commanders. The Outrider air vehicle had a range of 200 kilometers (km) with three hours endurance on-station. The air vehicle was designed to carry a day and EO/IR payload to conduct reconnaissance, intelligence, surveillance, and target acquisition missions.[31] The ACTD program was expected to last two years, with an Initial Operational Capability (IOC) achieved within four years.[32] Initial estimates call for $268M in development and $583M for procurement of 60 Outrider systems with 240 air vehicles.[33]

Due to some similarities among Navy and Army requirements, the Outrider program was declared a joint program by the Joint Requirements Oversight Council (JROC). At the time of program initiation, John W. Douglass, Assistant Navy Secretary for Research, Development, and Acquisition, believed the Outrider would be a success because of the efforts made to "harmonize the requirements of each military service."[34] On the contrary, compromises by both services resulted in a vehicle that was unacceptable to either service. The Army specified a 50 km range, but the range requirement was increased to 200 km to allow the Navy to launch the same vehicle from 50-100 miles offshore and still have several hours endurance on station.[35] Shipboard operation was to introduce the same electromagnetic interference problems that plagued the Pioneer UAV program. The Navy also added a heavy-fuel engine requirement, exacerbating problems that the prime contractor was having with the operational life and reliability of the engine.[36] Finally, the Navy increased the cost and weight of the imaging payload and datalink by adding a requirement for the Outrider to "record and transmit the image of an identifiable, tank-sized target from 125 miles".[37] These fundamental differences in service requirements created a difficult engineering challenge that increased the time needed for development and drove up the cost of the program.

Since the 2-year ACTD timeline was not extended, the development delays were made up for by shortening the duration and scope of the test program. The program manager shortened the Army and Marine Corps Military Utility Assessments from six months to four months and eliminated the shipboard testing phase.[38] The shortened evaluation period raised concerns among oversight agencies, which charged that neither system performance nor supportability would be adequately demonstrated.[39] The users shared these concerns. The Navy's director for expeditionary warfare, Marine Corps Major General Hanlon, was skeptical of the Outrider military user assessment saying, "I'm not sure we'll get a good maritime evaluation at Ft. Hood."[40] The limited testing that did take place allowed the evaluators to conclude that the Outrider would not meet its endurance goals at maximum range nor could it meet its transportability goal of requiring one C-130 aircraft.[41] Rather than transitioning into production as planned, the Outrider UAV program was cancelled at the conclusion of the ACTD.

Predator UAV

Figure 4: Predator UAV

The Medium-Altitude Endurance UAV (MAE UAV), also known as the Predator UAV, began in 1994 and was also among the first ACTD programs. The system is designed to provide 24-hour, near-continuous, on-station surveillance with a 500 nautical mile operational radius using EO/IR and SAR sensors with growth plans for moving target indication (MTI), signals intelligence (SIGINT), communications and data-relay payloads.[42] The 30-month ACTD program developed, manufactured and tested three ground control systems with ten air vehicles.[43] Development and procurement was initially estimated at $579M for 13 Predator systems with 80 air vehicles.[44]

The Predator UAV system was developed very rapidly. The first air vehicle began flight testing only six months into the ACTD. In fourteen months, the contractor delivered ten UAVs and three ground control stations for a military utility assessment conducted by U.S. Atlantic Command. The Predator UAV system performed so well in stateside joint exercises that Air Combat Command requested the immediate deployment of the Predator UAV to Albania. The system's performance during the 1995 deployment led U.S. Atlantic Command to declare the military utility of Predator and allowed the Air Force to seek a production decision from the DAB.

The transition into production led to problems for the Predator UAV program. As the first program to transition from ACTD to production, the Predator team had to create a transition process. Fourteen months passed before a production decision was reached by the DAB. Much of this delay came from the debate over the need for additional operational testing and efforts to define requirements for the production systems.

Operational testing was not conducted as a prerequisite to production and has therefore lost much of its influence over the Predator system design. Once the system was put into production, there was little motivation on the part of the users and developers to provide systems for operational testing. Operational testing was delayed over three years due to deployment commitments. Predator UAV squadrons have been almost continuously deployed since the system went into production. From 1994 through the end of 2000, Predator systems have logged over 20,000 flight hours.[45] Despite this record, the fleet still experiences unnecessary air vehicle losses, which have been linked to the system's "immaturity along with [a] lack of complete documentation and poor human factors design".[46] Rather than conducting a thorough evaluation of system capability and recommending improvements through the operational testing process, the Predator UAV system has discovered its shortcomings in the field and forced the user to adopt a piecemeal approach to upgrades.

The transition to production was further hampered by a lack of documented requirements. The development of an Operational Requirements Document (ORD) did not begin until after the ACTD ended and required 13 months of negotiation between the program office and the user.[47] The ORD is normally produced early in a program to guide the system design from the very beginning. The late addition of these operational requirements introduced additional changes to the system. A deicing system was required to prevent the build-up of ice on the wings, an improved video sensor was procured, and the ground control station was redesigned for greater portability. The transition from contractor to military maintainers required several rewrites of the maintenance technical orders in order to meet ACC standards. These requirement changes increased the cost of production systems and also forced a costly retrofit of the ACTD systems.

The failure to baseline requirements and thoroughly test the system's operational effectiveness and suitability has increased the cost of this program and slowed efforts to pursue future improvements. Configuration changes and supportability considerations nearly doubled the cost of the production systems. While a Predator ACTD system cost about $15M, a combat-ready production system with integrated logistics support provisions now costs nearly $30M.[48] This cost increase, along with the cost of upgrading the ACTD systems has slowed the rate of delivering new systems and reduced the amount of money available to adapt the Predator UAV to new missions.

Summary of Causes

Table 1: Causes of Past Program Failures

System	Type of Procurement	Problems
Pioneer UAV	Off-the-Shelf purchase	- Insufficient testing before purchase
Acquila UAV	Development	- Immature technology - Requirements growth
Hunter UAV	Development	- Contractual restrictions on developers - Poor system performance - Insufficient testing before production
Outrider UAV	ACTD	- Requirements growth - Poor system performance
Predator UAV		- Requirements growth - Insufficient testing before production

In nearly every program, changing or poorly understood requirements contributed to cost growth that threatened to end the program. Changing military requirements transformed both the Acquila UAV and Outrider UAVs into multi-role systems and led to their failure. The Pioneer UAV was procured without formally documented requirements and was then found to be unsuitable for shipboard operations. New requirements helped to double the cost of Predator UAV systems in production.

In several programs, the availability of technology and the performance of non-developmental items were taken for granted leading to unforeseen cost and schedule overruns. The Acquila program was unable to develop and integrate the subsystems needed to perform its mission. The engines for the Hunter UAV system were in service as motorcycle engines, but did not meet the Army's performance and reliability requirements when adapted for the air vehicle. The slow integration of non-developmental components contributed to schedule slips during the Outrider UAV system. Aggressive cost and schedule goals created unrealistic expectations for the users of these systems. The ACTD process, which is designed and funded for only a 2-4 year period, may exacerbate this problem.

Finally, several programs conducted insufficient testing before committing to production. Weapons systems programs are rarely killed after production begins, so developers often have an incentive to rush into production.[49] The Pioneer system was purchased for shipboard operations without sufficient testing in the proper EMI environment. The Army went ahead with Hunter UAV production before several key design problems could be overcome and was unable to field those systems. The Predator UAV system did not undergo formal operational testing until it was in production, so many of its problems were discovered in the field and had to be addressed through costly retrofits. During the Outrider UAV program, schedule slips during development came at the expense of testing, which further undermined user confidence in the system and contributed to the program's cancellation.

Chapter 3 examines the RQ-4A Global Hawk ACTD program and the X-45 UCAV ATD program for evidence that we are incorporating lessons learned into our current acquisition efforts.

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Chapter 3

Current UAV Programs

A comparative level of complexity was present during the live fire testing of four manned fighters firing four AMRAAM missiles at four unmanned QF-106 drones at Eglin AFB in 1995…to get four QF-106s airborne at low altitude in formation, pumping our chaff and jamming, was the functional equivalent of multiple space shuttle launches…Those who talk about putting 30-40 UCAVs in the air at the same time, each controlled by an operator 200 miles away, haven't thought out the problem.[1]

—Major Mike Loh, former commander of Air Combat Command

High Altitude Endurance (HAE) UAV

Figure 5: Global Hawk UAV

The HAE UAV program began under the management of Defense Advanced Research Projects Agency (DARPA) in 1994. DARPA combined two UAV requirements, the Tier II+

conventional high altitude endurance UAV (Global Hawk) and the Tier III- UAV (Darkstar), which would trade off some endurance and range for stealth. Both air vehicles were addressed in the initial ACTD program with the intent to develop complimentary platforms to provide near real-time reconnaissance, surveillance, and target acquisition information to theater commanders. The program's emphasis on affordability led to the cancellation of Darkstar UAV in 1998. The Global Hawk UAV is viewed as a low cost alternative to the purchase of additional U-2 reconnaissance aircraft. The Air Force currently has 31 U-2s in service, however only one third are available for missions at any given time due to maintenance and scheduled upgrades.[2] Additional U-2s are estimated to cost $20M each, while Global Hawk UAV offers much longer range and endurance for an estimated $15M, and correspondingly lower operating and support costs.[3]

Global Hawk is the largest of today's UAVs with a wingspan of nearly 120 feet. It carries an integrated 2000 pound sensor suite equipped with EO/IR and SAR sensors, a threat warning receiver, and airborne datalink.[4] Two 1000 lb. hardpoints on the wings will allow the UAV to carry multiple payloads and defensive avionics. The initial performance goals specified a system with 24 hour endurance over a target 1000 miles away at an altitude of 65,000 ft.[5] The production air vehicle will meet the endurance and altitude requirements at a range of 3000 nautical miles.[6] System performance throughout the development process has met these expectations.

In contrast to many of the aggressive timelines pursued during previous UAV programs, the HAE program has followed a relatively conservative development schedule. The HAE program was designated an ACTD in 1995, but not subject to the two-year schedule constraints associated with other ACTD programs. Early program schedules define a four-phase program, requiring six years to reach production.[7] A Department of Defense Inspector General report stated that the HAE program should not be pursued as an ACTD because its was not technically mature and could not be completed within 2-4 years.[8] However, the longer schedule was found to be appropriate given the Air Force's emphasis on lowering the program risk over more aggressive DARPA programs.[9] This realistic scheduling approach was combined with a simplified requirements process to create a more manageable program.

The HAE program's unique contracting approach has allowed the management team to focus on affordability and avoid the "requirements creep" that has crippled earlier programs. The HAE program was declared a Pilot Acquisition program under the 1994 National Defense Authorizations act, which allowed a waiver of Federal Acquisition Regulations resulting in a simplified and accelerated contracting process.[10] Minimal government oversight was provided by a government team estimated at only twelve people, which gave the contractor maximum flexibility in the design process.[11] Rather than requiring the contractor to meet a wide range or performance requirements, the government specified price as its only firm requirement. The program office established a cost cap of $10M unit flyaway price per air vehicle.[12] This management process is referred to as applying cost as an independent variable (CAIV). Under CAIV, all other performance goals can be traded off as necessary to maintain cost. These initiatives allowed the program managers to strive to for achieving the best value rather than optimizing performance at any cost and kept development on schedule.

The HAE has conducted sufficient testing to demonstrate military utility, but has wisely chosen to continue development by entering a formal Engineering and Manufacturing Development (EMD) phase following the completion of the ACTD. A user assessment was carried out under the leadership of U.S. Joint Forces Command from June 1999 – September

2000. The system successfully demonstrated the ability to fly 1200 nm and orbit for 24 hours over an area of interest at 60,000 feet.[13] Both EO/IR and SAR imagery was evaluated as well as the ability to relay imagery to strike aircraft in less than ten minutes.[14] The total test program was scheduled for 1200 flight test hours among four air vehicles, but concluded with only 700 hours of flight test time.[15] Despite falling short of their testing goals, some Air Force officials hoped to secure an early decision to proceed with LRIP and transition into full-rate production immediately after the ACTD. In July, 1999 the Under Secretary of Defense for Acquisition, Technology and Logistics directed the Air Force to postpone LRIP until after the completion of the ACTD and made it clear that the program would most likely require an EMD phase.[16] The GAO supported this decision to wait for the end of the ACTD and Military Utility Assessments before committing to EMD.[17]

The transition from ACTD to EMD has been approved and a development contract will be awarded later this year. In contrast to the Predator UAV program, the Concept of Operations (conops) and ORD have been prepared in advance to support this phase of development. During EMD, the contractor will make many system upgrades, to include global air traffic management, collision avoidance, see-and-avoid functions, and the installation of an anti-jam GPS capability.[18] Several new payloads will also be integrated, including SIGINT systems, moving-target indicator and foliage-penetrating modes for the radar.[19] Formal OT&E is planned before a full-rate production decision. Eight additional aircraft are expected to be produced over the next three years at a cost of $366M, bringing the total program cost to $772M.[20] While the Air Force is budgeting for a fleet of forty air vehicles, Northrop Grumman expects the eventual number of air vehicles to exceed one hundred.[21]

Unmanned Combat UAV (UCAV)

The UCAV Concept

The concept of an armed UAV specifically designed to perform the missions of manned fighters has existed for several years. A 1996 study by Air University has predicted the development of a stealthy offensive UAV with the ability to loiter for 24 hours at a range of 6000 kilometers with a payload of all-weather, precision weapons.[22] The UAV, referred to as "Deathstar" in the report, was envisioned to enforce an "air occupation" of a distant area without the need for overseas bases.[23] Some analysts predict that the need for UCAVs will intensify as enemy air defense networks become more effective.[24] Others have gone so far as to predict that the F-22 and Joint Strike Fighter will be the last manned fighter aircraft developed by the Department of Defense.[25] The reusability of UCAVs offers cost savings over cruise missiles and are expected to be more capable against moving targets.[26] Reductions in consumables, maintenance, and personnel are expected to reduce operations and support costs by 50-80% when compared to a tactical aircraft squadron.[27] Defense officials estimate that if the average UCAV survives nine missions, it will be the most cost-effective means of attacking many ground targets.[28]

UCAV Advanced Technology Demonstration (ATD)

Figure 6: X-45 UCAV Demonstrator

The UCAV demonstrator is intended to provide an affordable, effective means of conducting suppression of enemy air defenses (SEAD) and strike missions. UCAV is projected to cost $10M in production and is small enough that six can be carried in a C-17.[29] The all-electric aircraft can be stored in a small container for up to a decade and then unpacked and assembled in one hour.[30] Boeing is approximately half-way through the 42-month ATD that will result in the development, fabrication and flight testing of two demonstrator air vehicles and a mission control station. The first of the X-45A UCAV prototypes was rolled out in September, 2000. According to the program manager, LtCol Michael Leahy, the demonstrator program will eventually transition to a formal acquisition effort with the goal of an operational capability by 2010.[31]

The Air Force's UCAV ATD program is intended to demonstrate the maturity of the necessary technology and could lead to a formal requirement to further develop and produce these systems. ATD is a demonstration effort to help the service identify requirements and determine the readiness of key technologies to transition into a production program. An ATD differs from and ACTD because it does not necessarily attempt to produce an initial capability, but attempts to determine if it is "technically feasible and fiscally prudent" to continue development.[32] In contrast to earlier UAV procurements when systems were acquired without a thorough technical assessment, the UCAV ATD will provide the Air Force with a greater level of confidence in the system. Given the significant technical hurdles that need to be addressed at this time, the ATD process is an appropriate method of initiating UCAV development.

The UCAV demonstrator program provides the Air Force with an opportunity to further develop key technologies before committing to a full-scale development effort, thereby avoiding another of the conditions that have caused previous programs to fail. The employment of weapons from a UAV is not the greatest area of risk. Multiple Hellfire missile launches from a Predator UAV were successfully demonstrated earlier this year.[33] The simultaneous control of multiple UCAVs presents the program's most difficult technical problem. Some concepts of operation envision manned mother ships directing squadrons of as many as 10-16 UCAVs, which fly together in formation until the controller orders individual UCAVs to attack.[34] According to Armand Chaput, the Lockheed Martin UCAV program manager, "the technology exists today for one operator to control a single UCAV in almost any environment. The issue is multiple operators with multiple vehicles in the air at the same time."[35] Another key technology is robust, jam-proof communications during line-of-sight and over-the-horizon operations, according to Larry Birckelbaw, the program manager of DARPA's UCAV demonstration team.[36] Human factors issues also must be addressed to permit autonomous operations while keeping the human operator in-the-loop for targeting and weapons employment.[37] Progress in these areas will aid the Air Force in the development of appropriate conops and requirements for the production UCAV system.

The UCAV program is taking a remarkably open approach to requirements development that should reduce the inefficiencies of changing or poorly understood requirements experienced during earlier programs. The government is not constraining the developer with traditional specifications or statements of work in order to allow the contractors to balance capability with affordability.[38] By allowing performance trade-offs to be worked out with the developers, the Air Force does not prematurely specify requirements that will unnecessarily constrain the design or result in contradictory direction later in the program.

Finally, joint service interest is yet another factor that can affect the development of the UCAV. In June, 2000 the Navy awarded two additional contracts for a 15-month study resulting in the preliminary design for a sea-based UCAV to conduct SEAD, strike and surveillance missions.[39] This effort is designed to capitalize on Air Force UCAV efforts, and address the additional areas of shipboard integration and service-specific missions.[40] It is unclear whether or not this effort will result in a joint USAF/Navy UCAV program. Given the additional problems experienced by earlier joint UAV programs such as Outrider, the services must account for differences in requirements and missions when planning this joint development effort.

Notes

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Chapter 4

Conclusions

UAVs have rapidly gained the attention of military commanders for good reasons. They are relatively inexpensive and can effectively accomplish vital missions without risking human life. We already have sufficient experience with UAVs to know that they will revolutionize warfare.

—Rear Admiral Barton D. Strong
former Program Executive Officer for Joint UAVs

Global Hawk UAV

The Global Hawk ACTD is avoiding many of the pitfalls identified during prior UAV development efforts. The system's performance during the ACTD evaluations clearly demonstrates that the technology is available to conduct this mission. The system demonstrated its key capabilities during the user assessments and the only air vehicle crash during testing was traced to human error rather than system failures. While other ACTDs did not place enough emphasis on requirements development, the HAE program has documented operational requirements prior to the end of the ACTD and has had good interaction with the user. The CAIV process adopted by the HAE UAV program weighs the increased performance against its effect on cost and schedule. CAIV allows design flexibility by the developers while still limiting the risk of requirements creep. As a result, the HAE ACTD has demonstrated that the Global Hawk can meet key performance goals and remain affordable.

The decision this summer by the DAB to transition the HAE program into an EMD phase was the right one. The EMD effort will provide an opportunity to make the system more robust before it becomes operational and avoid the costly retrofits that have plagued the Predator UAV program. The DAB is being appropriately cautious regarding the construction of additional prototypes. The Air Force's latest request for additional air vehicles was conditionally approved following the resolution of several unknowns. These unknowns included the actual costs to build the first five air vehicles, the completion of the ORD, and the analysis of alternatives, in addition to the results of ongoing flight testing. The GAO states that "eliminating these unknowns before an acquisition decision is consistent with the best practices of leading commercial firms".[1]

One area where the HAE program will benefit the most from an EMD phase is the opportunity for further flight testing. Schedule pressures have contributed to insufficient testing during many of the previous UAV programs. The HAE program conducted 700 hours of flight testing, but the ACTD ended before the entire 1200 hours of flight testing could be completed. The incomplete testing increases the workload during EMD and increases the likelihood of discovering problems during later developmental and operational testing. The DAB recognizes the need to conduct these evaluations before fielding the system, and the completion of EMD provides the best chance of developing a system that is both capable and affordable.

UCAV

The UCAV ATD program approach is appropriate given the current state of requirements and technology. An ACTD is not justified because an off-the-shelf capability does not exist and the concept of operations has not been developed. The ATD provides an opportunity to refine the concept of operations and demonstrate the ability to conduct the SEAD and strike missions under controlled conditions. UCAV employment is going to require close coordination with other air force weapons systems, so operators must have a high level of confidence in the system. Additionally, UCAV's infringement on current manned missions will make it vulnerable to criticism when inevitable failures occur. The ATD program is an opportunity to cultivate support among the users, which is likely to be needed as the program continues to push through its initial learning curve.

Once requirements are known and technology demonstrated, the formal acquisition process should be initiated. Operational requirements need to be documented up front, to avoid the unnecessary delay between phases of development experienced during the Predator UAV program. Cost considerations may make a joint Air Force/Navy program attractive, but caution should be used to avoid a repeat of the requirements growth experienced during the joint Outrider UAV program. Requirements growth can continue to be managed through a continued emphasis on affordability and tools such as CAIV. The UCAV program should continue to allow the contractor flexibility in the design process and avoid introducing additional contracting limitations as experienced in the Hunter UAV program.

All of the UAV programs examined in this research testify to the importance of thorough developmental and operational testing. UCAV flight testing will begin in spring, 2001 at Edwards AFB, CA. Given the historical risk associated with insufficient testing, the UCAV ATD should be extended as necessary to ensure the key performance parameters are verified. In addition, operational testing needs to be conducted during EMD and a production commitment should not be made until the results of testing are available.

The overall conclusion of this research is that many of the lessons learned from recent UAV program failures have been addressed by the HAE and UCAV programs. Many of the problems encountered in earlier programs resulted from an overconfidence in the available technology or shortcomings in the requirements and testing processes. The Air Force appears to be taking a more deliberate and restrained approach to the development of the HAE and UCAV systems. This conservatism is justified and is likely to result in the fielding of systems with well-understood capabilities and costs. There is no substitute for solid engineering and testing practices, and these programs appear to be building a foundation that will assure their long-term affordability and effectiveness.

Notes

[1] "Global Hawk Goes Global", 14.

Glossary

ACTD	Advanced Concept Technology Demonstrator
ATD	Advanced Technology Demonstrator
CAIV	Cost as An Independent Variable
Conops	Concept of Operations
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
EMD	Engineering and Manufacturing Development
EMI	Electromagnetic Interference
EO/IR	Electro-optical/Infrared
GCS	Ground Control Station
HAE	High Altitude Endurance (HAE)
IOC	Initial Operational Capability
JROC	Joint Requirements Oversight Council
Km	Kilometers
LRIP	Low-Rate Initial Production
LUT	Limited User Testing
MAE	Medium-Altitude Endurance
MTI	Moving Target Indication
MUA	Military User Assessment
ORD	Operational Requirements Document
SAR	Synthetic Aperture Radar
SEAD	Suppression of Enemy Air Defenses
SIGINT	Signals Intelligence
UAV	Unmanned Aerial Vehicle

UCAV	Unmanned Combat Air Vehicle

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